Chapter 4

Summary of Studies in Midway Valley

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Abstract

Midway Valley, a gently east sloping alluviated lowland lying east of Yucca Mountain in southwestern Nevada, has been studied extensively as the location for surface facilities associated with the proposed underground repository site for the storage of high-level radioactive wastes. Detailed geologic mapping, logging of trenches across faults, core drilling, and geophysical surveys provide data for determining the location and recency of faulting with respect to the proposed surface facilities.

The Tiva Canyon Tuff of Miocene age forms the bulk of bedrock exposed in the hills and ridges directly east, west, and south of Midway Valley, and post-Tiva Canyon rocks are exposed to the north. Surficial deposits, ranging in age from early Pleistocene to Holocene, that blanket the valley floor have been divided into eight map units for the purpose of determining the history of sedimentation and faulting during the Quaternary.

Structurally, Midway Valley is an east-dipping half-graben that is elongate north-south and bounded by two north-trending, west-dipping normal faults along the valley margins: the Bow Ridge Fault to the west and the Paintbrush Canyon Fault to the east. These two faults vertically displace bedrock as much as 125 and 500 m, respectively, and both faults display evidence of Quaternary activity. A series of inferred small-scale north-trending normal faults has been projected beneath the surficial deposits flooring the valley; one of these faults, in central Midway Valley (Midway Valley Fault) is depicted as having an estimated down-to-the-west displacement in bedrock of several tens of meters. The presence of such faulting is supported by geophysical data; however, no evidence was observed for displacement of the overlying surficial deposits within the valley.

Three trenches, excavated across faults on the east side of Exile Hill (west edge of Midway Valley), expose fractured but unfaulted Quaternary deposits overlying a bedrock fault (Exile Hill Fault). Although fracture zones were observed in alluvial deposits exposed in one of these trenches, as well as in some test pits east of Exile Hill, no bedrock was exposed in the excavations to determine the relation of the fractures to any known fault. A fourth trench was located across a projected trace of the Bow Ridge Fault north of Exile Hill, but no evidence of displacement of the exposed alluvium was observed. However, Quaternary faulting events are conspicuously displayed in trenches across the Bow Ridge Fault on the west side of Exile Hill and across the Paintbrush Canyon Fault at the south end of Midway Valley. Neither of these two faults is in areas where future surface ruptures would intersect the proposed site of surface facilities in Midway Valley.

Introduction

Midway Valley, lying between Yucca Mountain on the west and Alice and Fran Ridges on the east (figs. 1, 2), forms a gently east sloping alluviated lowland crossed by drainages heading in Drill Hole, Pagany, Sever, and Yucca Washes to the west and northwest and flowing eastward into Fortymile Wash. The valley has been considered as the location of surface facilities associated with the proposed repository site for the storage of high-level radioactive wastes beneath Yucca Mountain to the west (Neal, 1985). Accordingly, the geology of Midway Valley has been the subject of extensive study during the Yucca Mountain site-characterization program, with the general objective of acquiring surface and near-surface geologic data on the stratigraphic and structural relations of Quaternary deposits and Tertiary bedrock. Such data are required to evaluate the potential for future faulting and seismicity near the proposed site of surface facilities for the handling of high-level radioactive wastes.

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This chapter briefly summarizes the results of detailed geologic mapping, logging of trenches across faults, core drilling, and geophysical profiling that have been conducted for the specific purpose of ascertaining the location and recency of faulting near the proposed surface facilities in Midway Valley; such studies were discussed in detail by Swan and others (2001). Additional sources of published data include the maps and reports by Scott and Bonk (1984), Neal (1985, 1986), Gibson and others (1992), Wesling and others (1992), Ponce (1993), Ponce and Langenheim (1994), Simonds and others (1995), and Day and others (1998a).

Geologic Setting

Bedrock Stratigraphy

The Miocene Tiva Canyon Tuff forms the bulk of bedrock exposed in the hills and ridges directly east, west, and south of Midway Valley, and post-Tiva Canyon rocks (rhyolite of Comb Peak) are exposed to the north (Scott and Bonk, 1984; Day and others, 1998a). The Tiva Canyon is one of the younger formations in the Paintbrush Group, which consists of an extensive series of welded and nonwelded silicic pyroclastic flow and fallout tephra deposits and volcanic breccia erupted from nearby calderas in the southwestern Nevada volcanic field (Sawyer and others, 1994). In addition to voluminous pyroclastic deposits, the Paintbrush Group also contains lava flows and domes, such as the rhyolites of Delirium Canyon, the rhyolite of Vent Pass, and the rhyolite of Black Glass Canyon. Other units exposed locally at the surface and (or) penetrated in shallow excavations and boreholes include the Topopah Spring and Pah Canyon Tuffs of the Paintbrush Group and the Rainier Mesa Tuff of the Timber Mountain Group. Each of these formations has been subdivided to facilitate detailed geologic mapping and the measuring of fault offsets (for example, Buesch and others, 1996). The total thickness of Tertiary volcanic rocks in the study area exceeds 1,200 m, on the basis of data from borehole UE–25p#1 at the extreme south end of Midway Valley (Muller and Kibler, 1984).

Surficial Deposits

Midway Valley is blanketed by surficial deposits composing a stratigraphic sequence that is closely similar to the eight alluvial units (such as units QT0 and Qal, tables 2, 3) described in chapter 2. Colluvial deposits of colluvium (such as units QTc and Qcl, pl. 1), which interfinger with correlative alluvial deposits near the valley margins, have also been dis-

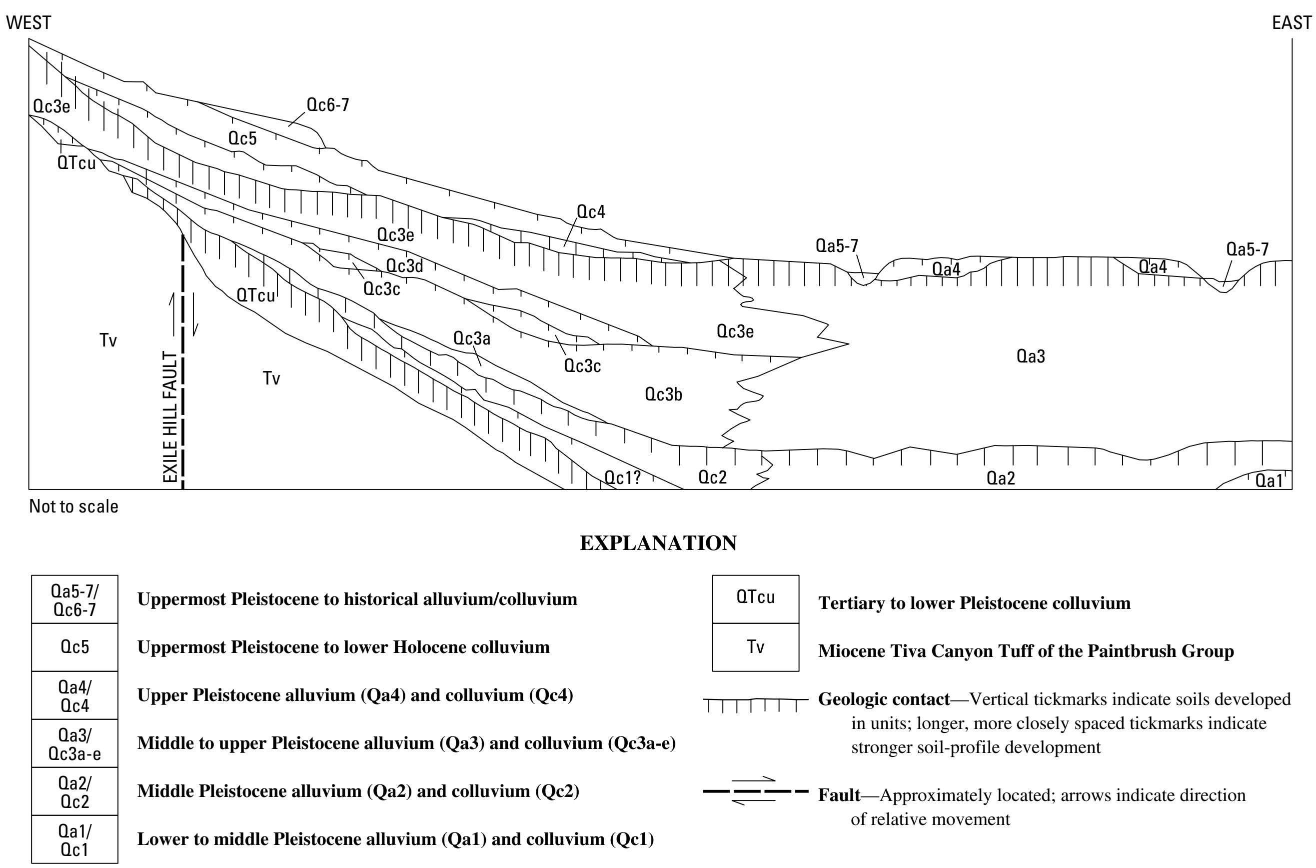

Figure 5. Schematic cross section showing stratigraphic relations among bedrock, alluvium, and colluvium in western Midway Valley, southwestern Nevada (from Swan and others, 2001).

tinguished (fig. 5). The colluvial sequences are readily observable only in test pits and trenches excavated along the east side of Exile Hill, at the west edge of the valley (pl. 1; fig. 6).

Structure

Midway Valley is a half-graben, elongate north-south, that is bounded by two north-trending, west-dipping normal faults along the valley margins: the Bow Ridge Fault to the west, on the west side of Exile Hill (fig. 7); and the Paintbrush Canyon Fault to the east (fig. 4; Scott and Bonk, 1984; Simonds and others, 1995; Day and others, 1998a). These two faults vertically displace bedrock as much as 125 and 500 m, respectively, and both faults display evidence of Quaternary activity. The Bow Ridge and Paintbrush Canyon Faults are discussed in chapters 3 and 5.

Cross sections drawn across the valley by Scott and Bonk (1984), Carr (1992), and Day and others (1998a) show a series of inferred small-scale normal faults beneath the surficial deposits; one of these faults, in central Midway Valley, is depicted as having an estimated down-to-the-west displace-

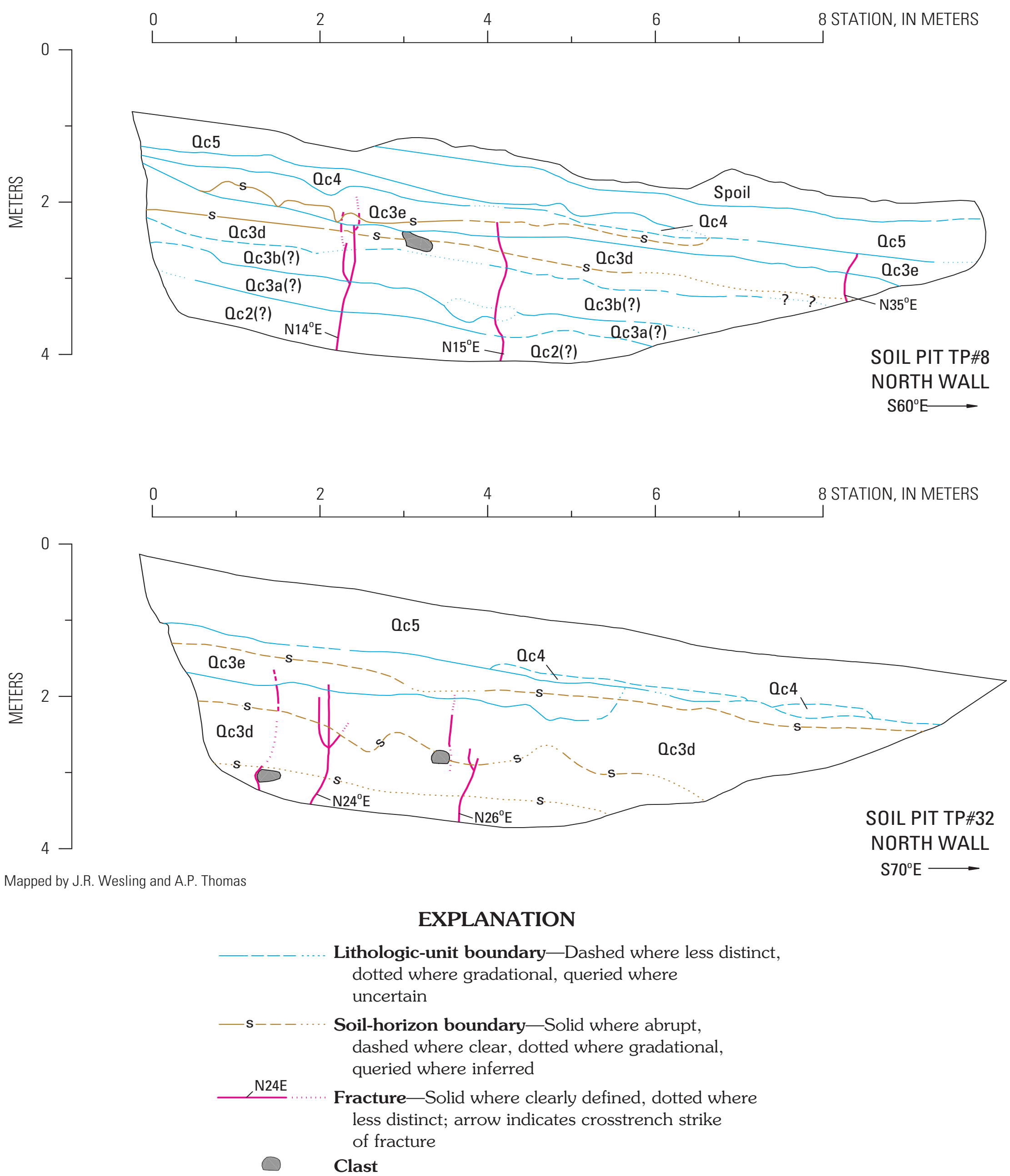

Figure 6. Cross sections of test pits shown in figure 8 (see fig. 5 for explanation of map units).

ment of several tens of meters in the underlying bedrock. This fault, considered to be the northward extension of a west-dipping normal fault mapped in the Tiva Canyon Tuff in the southern part of Bow Ridge (Scott and Bonk, 1984; Day and others, 1998a), was referred to as the Midway Valley Fault (fig. 4) by Neal (1986). Lipman and McKay (1965) and Day and others (1998a) extended the fault to the north-northeast for more than 6 km through central Midway Valley. Anomalies attributable to the presence of concealed faults have also been detected by electromagnetic-sounding data (Frischknecht and Raab, 1984), other resistivity/geoelectric surveys (Fitterman, 1982; Senterfit and others, 1982; Smith and Ross, 1982), and gravity and magnetic surveys (Ponce, 1993; Ponce and Langenheim, 1994). The combined evidence thus supports the interpretation that one or more buried faults displace the bedrock within Midway Valley (fig. 7); however, no surface displacements of surficial deposits have been observed along the projected traces of any of these faults.

The trace of a north-striking, steeply east dipping normal fault, named the Exile Hill Fault (fig. 8), was projected beneath surficial deposits along the east edge of Exile Hill by Day and others (1998a). The fault is shown to merge southward with the Midway Valley Fault. Original detection of this buried feature was based on electrical-resistivity data (Senterfit and others, 1982; U.S. Geological Survey, 1984). Subsequently, seismic reflection and refraction surveys (Neal, 1986), as well as gravity and ground magnetic data (Ponce, 1993; Ponce and Langenheim, 1994), were interpreted to indicate the presence of minor faulting along the east base of Exile Hill (see next section).

Two north-northwest-trending, near-vertical normal faults displace units of the Tiva Canyon Tuff exposed at Exile Hill (figs. 7, 8), and terminate southward against the Exile Hill Fault near the proposed site of surface facilities at the east edge of the hill (fig. 8). The East Portal Fault, which crops out along the east side of Exile Hill, is well exposed in the cutslope of the North Portal of the Exploratory Studies Facility

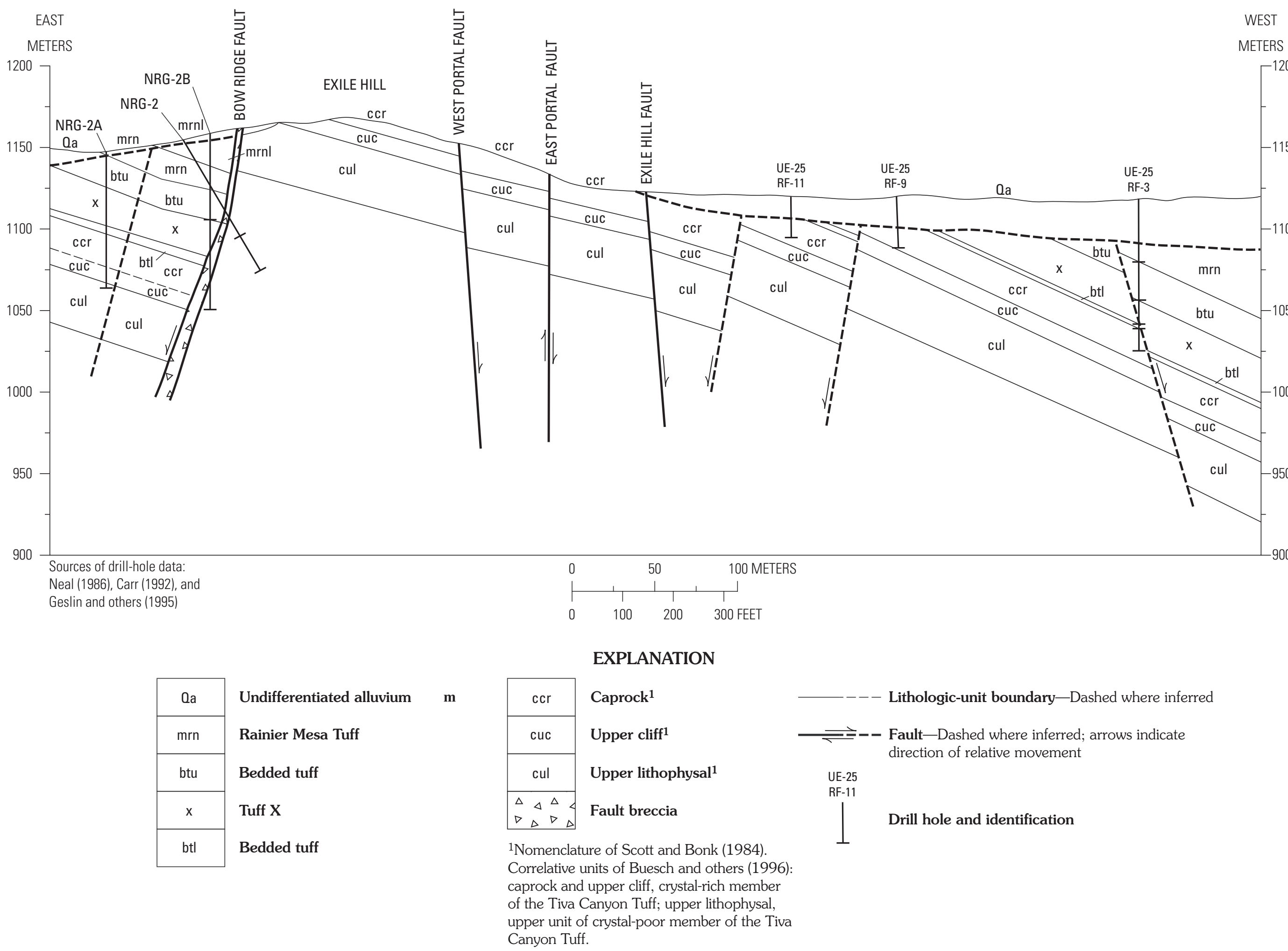

Figure 7. Cross section showing structure across Exile Hill and western Midway Valley, southwestern Nevada (from Swan and others, 2001) (see fig. 8 for locations).

(ESF) that is located near borehole UE–25 NRG#1 (fig. 8). The exposed segment of the fault strikes N. 7° W., dips steeply west to vertical, and exhibits slight right-lateral movement. Its surface trace in the Tiva Canyon Tuff has no geomorphic expression, and where buried by a thin mantle of upper Quaternary alluvium, these deposits do not appear to be displaced. At the North Portal excavation, the fault zone is 3 to 4 m wide, and the apparent down-to-the-east displacement in bedrock is 30 to 40 m. To the southeast, the East Portal Fault terminates abruptly against the Exile Hill Fault (as is readily observable in the North Portal excavation). From a point northwest of the northern peak of Exile Hill, the West Portal Fault extends

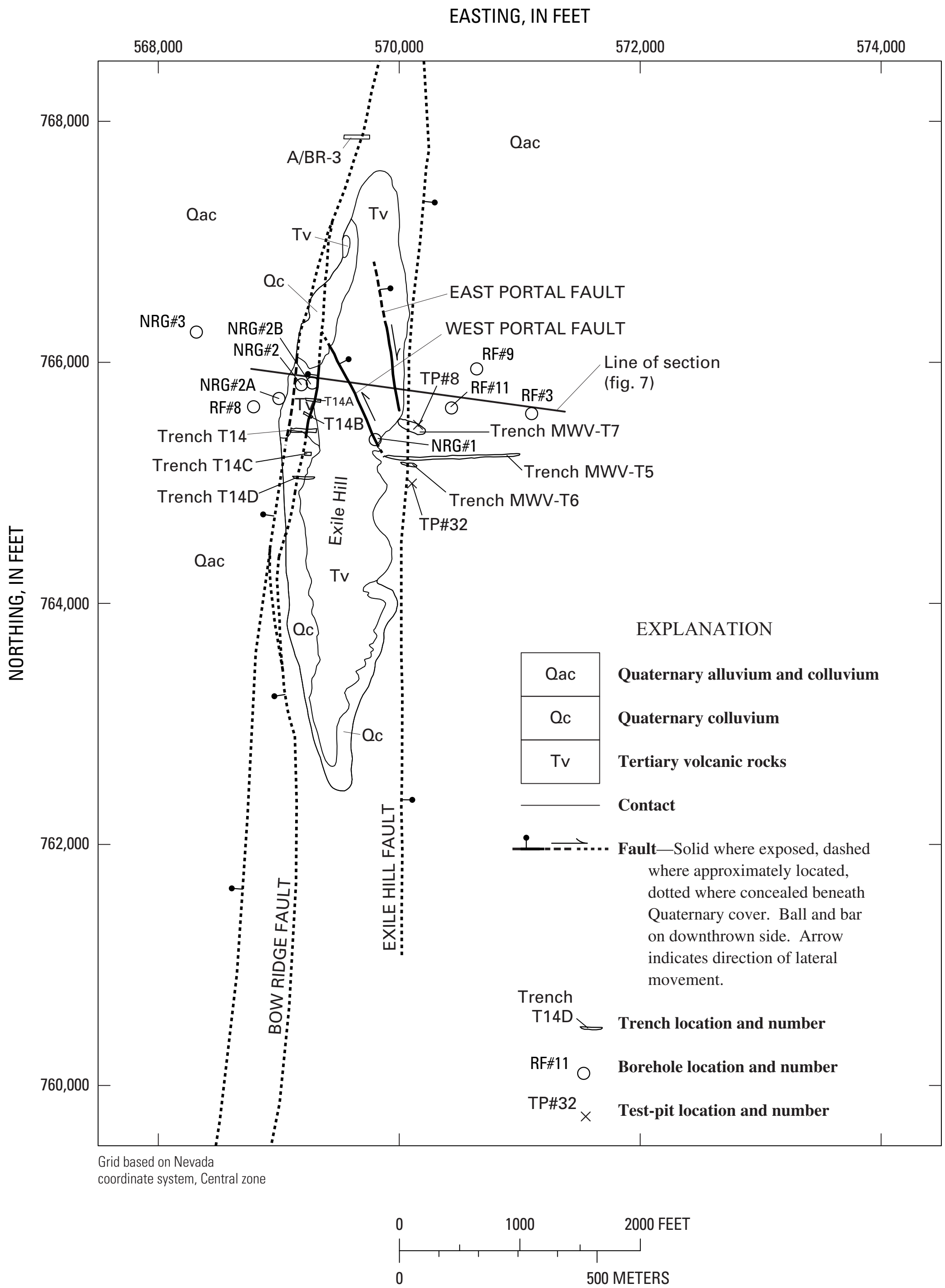

Figure 8. Exile Hill area, southwestern Nevada (fig. 2), showing general geology and locations of faults, trenches, test pits, and boreholes (labeled without prefix “UE–25”). North Portal of Exploratory Studies Facility is near borehole NRG#1. Adapted from Swan and others (2001).

southeastward to where it also terminates against the Exile Hill Fault, a distance of about 500 m (fig. 8). The fault strikes about N. 20° W., dips 88° NE., and displays down-to-the-east displacement with a minor left-lateral component. In exposures, the fault consists of a breccia zone, less than 1 m wide. At its northwest end, units of the Tiva Canyon Tuff locally are vertically offset about 10 m, and maximum displacement elsewhere along the fault is estimated at less than 15 m. Quaternary colluvium does not appear to be displaced by the West Portal Fault.

The strike-slip faults mapped along Drill Hole, Pagany, and Sever Washes project southeastward toward the west edge of Midway Valley but were shown to terminate against a strand of the Bow Ridge Fault west of Exile Hill on the map by Day and others (1998a). These faults are described in chapter 3.

Trenching Activities and Results

A principal element in the program of geologic and related studies in Midway Valley was the selection of sites for test-pit and trench excavations, the mapping of which would provide data needed to (1) identify possible Quaternary fault movements with respect to proposed surface facilities for the handling of high-level radioactive wastes, and (2) characterize the amount and timing of possible Quaternary displacements. During the course of the investigations, three trenches (MWV–T5, MWV–T6, MWV–T7, fig. 2) were excavated across faults on the east side of Exile Hill (fig. 8). Trench MWV–T7, which is located within one of the sites for proposed surface facilities (Neal, 1985), exposes stratigraphic and structural features representative of the geologic relations along the west side of Midway Valley at Exile Hill (pl. 1). A fourth trench (A/BR–3) was excavated across a projected trace of the Bow Ridge Fault north of Exile Hill (fig. 8), and a fifth trench (MWV–T4) across the trace of the Paintbrush Canyon Fault at the south end of the valley (fig. 2; see chap. 5). In addition, some 30 test pits were excavated at selected localities and described to characterize the soils and lithology of deposits associated with each of the principal surficial deposits and to facilitate the correlation of map units within the study area.

The Exile Hill Fault is exposed in bedrock in trench MWV–T7 (“crushed” zone 3, pl. 1), as well as in trenches MWV–T5 and MWV–T6, and in the North Portal excavation. Structural and stratigraphic relations among these exposures indicate a stratigraphic throw (down to the east) of as much as 15 m or less within the Tiva Canyon Tuff (fig. 7). Average dip is greater than 80° E. Steeply dipping, northeast-striking fractures that break, but do not measurably displace, upper Pleistocene and older colluvial deposits were identified in these trenches, as well as in test pits that were excavated across the fault; the fracture systems observed in trench MWV–T7 and in two of these test pits are shown in plate 1 and figure 6, respectively. The fractures in the colluvium, within a zone about 15 m wide, are traceable downward into northeast-trending bedrock faults that define the main trace of the Exile Hill Fault (for example, within “crushed” zone 3, pl. 1). Mapping and related studies of the faults and fractures clearly demonstrate the following relations:

1. Upper Pleistocene deposits (units Qa4, Qc4, pl. 1) are essentially continuous, are not displaced by surface faults, and are not fractured (fig. 6).
2. Known and inferred bedrock faults are overlain by lower to upper Pleistocene deposits (units Qc3/Qa3, Qc2/Qa2, Qcl/Qal, pl. 1) that have distinct soil and lithologic horizons which are fractured but not measurably displaced (within the limits of mapping resolution, which mostly ranges from 0 to 5 cm).
3. Locally, the contact between much older (Pliocene? to lower Pleistocene) cemented calcrete soils and bedrock appears to be offset slightly downward (≤10 cm) across minor shears in the Exile Hill Fault zone (for example, stas. 24–30, pl. 1). Carbonate- and silica-filled fractures in unit QTc are continuous with bedrock shears. The fractures either die out within unit QTc or are truncated at the QTc-Qcl? contact, and they are discontinuous with fractures in the overlying colluvium (unit Qcl and younger). Fractures that disrupt the colluvial sequence are observable east of these steps at the QTc-Tv contact.

A second fracture zone was observed in alluvial deposits near the east end of trench MWV–T5 (figs. 2, 8), as well as in test pits, approximately 155 m east of Exile Hill. No bedrock exposures were observed in these excavations, however, to determine the relation of the fracture zone to any known fault. No displacement of lithologic contacts and soil horizons within the Quaternary units could be detected.

The origin of the fractures in the Quaternary deposits is uncertain. Nontectonic causes cannot be completely ruled out, including such mechanisms as (1) fracturing caused by an ephemeral disruption during the transmission of seismic waves (for example, strong ground shaking from an earthquake on a nearby fault), and (2) release of residual stress in the Tertiary bedrock. However, despite the presence of faults and fractures widely varying in trend along the fault zone at the base of Exile Hill, fracturing does not explain why Quaternary fractures are associated with only the north- to northeast-trending faults. The episodic, though infrequent, development of tension fractures during the early Quaternary and mid-Quaternary is also difficult to explain simply by release of residual stress, as in mechanism 2. Partial release of residual stress in shallow rock during successive, widely separated episodes on a preexisting bedrock fault seems unlikely without an external triggering mechanism. Paleoseismic data indicate repeated mid-Quaternary to late Quaternary surface ruptures on the Bow Ridge and Paintbrush Canyon Faults, which bound the Midway Valley structural block (see chap. 5). Given the apparent episodic occurrence of the fractures and their consistent north-northeastward orientation, continuity along strike, and coincidence with the Exile Hill Fault and other faults in the underlying Tertiary bedrock, a more likely explanation is that the Quaternary fractures represent minor intrablock deformation of the otherwise relatively stable

Midway Valley structural block, triggered by activity on block-bounding faults, rather than from nontectonic causes.

Minor northwest-trending bedrock fractures and shears, possibly associated with the East Portal Fault, were observed in the west end of trench MWV–T7 (pl. 1; fig. 2). None of these northwest-trending fractures or shears, also observed in trench MWV–T5, extends upward into the overlying lower to middle Pleistocene colluvial deposits, and they do not cause offset of the bedrock-colluvium contact.

Trench A/BR–3 (figs. 2, 8) was excavated across two subparallel photolineaments defined by a weak alignment of vegetation. The photolineaments coincide with the projected northward trace of the Bow Ridge Fault as mapped by Scott and Bonk (1984) and Day and others (1998a). The trench was excavated in alluvial-fan deposits similar in age to those at or near the surface on the east side of Exile Hill. No evidence was observed during detailed mapping of the sedimentary contacts and soil-horizon boundaries to indicate that any of the deposits or soils are displaced or otherwise deformed by faulting, at least to the extent detectable within the limits of resolution of the mapping techniques used.

Trenches across the Bow Ridge Fault on the west side of Exile Hill (trench 14 complex, fig. 8) and along the Paintbrush Canyon Fault trace on the east side of Midway Valley (for example, trenches A1, MWV–T4, figs. 2, 8) are described in chapter 5.